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Marginal Rail Infrastructure Costs in Finland 1997 - 2002

Juha Tervonen and Tiina Idström

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Abstract

According to economic theory, efficient use of transport networks is reached by short-run marginal cost pricing. Charges on the use of the rail network should be set according to marginal wear and tear of tracks caused by each user. Capital costs of the existing network are not included in marginal cost pricing. Therefore, pricing the use of tracks requires separating variable and fixed rail infrastructure costs from each other.

Marginal rail infrastructure costs can be derived from a cost function on the statistical relationship of variable infrastructure costs and changes in the use of tracks. The marginal change in the variable infrastructure cost per unit of performance, e.g. a gross tonne-kilometre, is the fair and efficient price for track use.

Idström (2002) estimated the marginal costs of infrastructure use in Finland for the years 1997 – 1999 based on a methodology adopted from Sweden. In this study, the estimation was repeated with traffic and variable cost data for the years 2000 – 2002.

The main results on marginal costs for the years 2000 – 2002 are (in nominal prices):

- Calculated from all variable costs, the weighted average of marginal costs is 0.077 – 0.087 cents/gross tonne-kilometre.
- Calculated from maintenance costs, the weighted average of marginal costs is 0.018 – 0.025 cents/gross tonne-kilometre.

The main results on marginal costs for the years 1997 – 2002 are (at the 2002 price level):

- Calculated from all variable costs, the weighted six-year average of marginal costs is 0.11 cents/gross tonne-kilometre.
- Calculated from maintenance costs, the weighted six-year average of marginal costs is 0.016 cents/gross tonne-kilometre.

Compared with the results of the previous study (1997 – 1999), the level of marginal costs calculated from all variable costs decreased significantly in 2000 – 2002. The main reason for this is that budgets for replacement investments were significantly lower in 2000 – 2002. The constant fluctuation of replacement investment budgets is problematic in the short run for setting stable prices on infrastructure use.

The other important explanation is that there is a deficit of variable costs in estimation data because of the manner in which variable costs are registered into the cost monitoring systems. Several variable cost items could not be allocated to track sections as a result of imperfect information on the locations where maintenance and replacement investments had taken place. Also, the share of costs registered as overhead has slightly risen. These reasons lead to variable costs being left out of the estimation. Therefore, there is full justification to say that the above results are underestimates of the marginal infrastructure costs. This also sets out requirements for developing the cost monitoring systems.

The way the results from the six-year data set present the marginal costs even out the impacts of annually fluctuating budgets and inflation. Such a result is perhaps the most justifiable basis for setting infrastructure charges.

Foreword

In 2003, the Finnish Rail Administration began a study on the marginal costs of rail infrastructure use in 2000 – 2002. It is a follow-up to a similar prior study that was conducted with data for 1997 – 1999. Periodical assessment of marginal rail infrastructure costs is important for the purpose of pricing track use.

The members of the Steering Committee of this study were Mr. Martti Kerosuo, Mr. Harri Lahelma and Mr. Vesa Kärkkäinen from the Finnish Rail Administration and Mr. Tuomo Suvanto from the Ministry of Transport and Communications.

This report was prepared by the consultants of the project, Mr. Juha Tervonen (JT-Con) and Ms. Tiina Idström (JP-Transplan Oy).

Helsinki, in June 2004

Finnish Rail Administration

Traffic System Department

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1 Introduction

According to economic theory, efficient use of transport networks is reached by short-run marginal cost pricing. Charges on the use of the rail network should be set according to marginal wear and tear of tracks caused by each user. Capital costs of the existing network are not included in marginal cost pricing. Therefore, pricing the use of tracks requires separating variable and fixed rail infrastructure costs from each other.

Marginal rail infrastructure costs can be derived from a cost function which explains statistically how variable infrastructure costs vary according to changes in the use of tracks. The marginal change in variable infrastructure cost per unit of performance, e.g. gross-tonne kilometre, is the fair and efficient price for track use. Marginal costs are calculated according to the realized variable infrastructure costs, which is not necessarily equivalent to the optimal level of infrastructure financing.

Idström (2002) estimated the marginal costs of infrastructure use in Finland for the years 1997 – 1999 based on a methodology adopted from Sweden. The results are in use in the Finnish railway charging system. In this study, the estimation procedure is repeated with data on traffic and variable costs for 2000 – 2002.

The study serves various purposes. The methodology is tested once again in order to see whether the new results are logical compared with the results of the previous study. The estimates reveal how the shape of the cost function and the level of marginal costs change according to annual changes in traffic volumes and the variable costs allocated to the network.

It is now also possible to estimate the cost functions and the marginal costs based on a six-year data set (1997 – 2002). Therefore, the impacts of annually fluctuating budgets, as well as the impact of inflation, can be evened out. This study also highlights the needs for developing the systematics of marginal cost estimation. This concerns first and foremost the quality of background data that is used for creating data sets on variable infrastructure costs.

The report is set out as as follows. Section 2 describes the role of marginal infrastructure costs in the Finnish railway charging system. Section 3 describes the theoretical background and the mathematical methodology for estimating the variable cost functions and deriving the marginal infrastructure costs. Section 4 presents the main results of the previous Finnish study. In Section 5, the creation of data sets is described. Section 6 presents the results of this study and compares them with the results of the previous study. In Section 7, the strengths and weaknesses of marginal infrastructure cost pricing are listed. Also a comparison with average cost pricing is made. Section 8 presents the conclusions.

2 Finnish Rail Infrastructure Charges

In Finland, pricing the use of the railway network is regulated by the Directive on Railway Charging (European Commission, 2000) and the Finnish Law on Railway Network Taxes (2003/605).

A minimum requirement set out for infrastructure charging in the Directive is that the users of railway networks are charged according to the infrastructure costs that are caused by the use of tracks. In Finland, infrastructure charges are collected according to the use of the railway lines. The use of tracks at stations or marshalling yards is not charged. The Finnish charging system consist of a basic charge and an infrastructure tax, both set separately for passenger and freight trains (Table 2.1).

Table 2.1. Infrastructure charge in Finland (Finnish Rail Administration, 2003a).

Charges	
Basic charge	Freight traffic: 0.12227 cents/gross tkm* Passenger traffic: 0.1189 cents/gross tkm
Infrastructure tax	Freight traffic - electric: 0.05 cents/gross tkm - diesel: 0.1 cents/gross tkm Passenger traffic: 0.01 cents/gross tkm

* tkm = tonne-kilometre

The basic charge has been defined by estimating the marginal infrastructure costs of the use of tracks first by each track section separately in 1997, 1998 and 1999. A weighted average of the marginal costs has been calculated over the whole network from the results (Idström, 2002).

The Ministry of Transport and Communications (2002) states that the basis for defining the level of basic charges and infrastructure taxes should be assessed periodically in order to allow for the changes in infrastructure quality and traffic volumes.

3 The Calculation Method

3.1 Overview of the Calculation Method

The expert advisors of the European Commission have recommended a best practice for defining charges based on variable infrastructure costs. First, a function for variable infrastructure costs is estimated, and then the marginal cost of infrastructure use is derived from the parameter values of this cost function (European Commission, 1999).

This procedure involves the following phases:

- Infrastructure costs are categorised into fixed and variable cost items according to whether or not they vary by track use in the short run.
- The network is partitioned into sections for which statistical data either is known or can be produced.
- The variables of the cost function are listed according to the assumed relationships with the variable infrastructure costs.
- Statistical data on the variables of the cost function is collected at the level of detail determined by the network partitioning; traffic volumes (gross tonnes), variable costs and technical data on the track sections (length of track section, total length of tracks per section, number of switches, speeds and service level of track section).
- The statistical data is allocated to the partitions of the network.
- The cost function is estimated, and the statistical relationship between the variable infrastructure costs and track use, as well as the techical features of the network, are revealed.
- The cost function is differentiated with respect to traffic volumes which reveals the marginal relationship between the variable infrastructure costs and a change in track use.
- The marginal costs of track use per track section are used for calculating weighted averages over the network, or parts of it.

The critical issue in procedure is obtaining detailed data. The network partitioning should be rather dense in order to reveal the differences in marginal costs on track sections with different levels of traffic and variable costs. Therefore, the requirements for detail are high. The information described above should be assigned to each track section as accurately as possible.

3.2 Fixed and Variable Infrastructure Costs

Fixed infrastructure costs are considered to be capital costs of the existing infrastructure. These costs do not vary in the short run, and they do not vary by the use of tracks. Variable infrastructure costs do vary in the short run, and this variation has a direct relationship with the use of infrastructure.

The marginal costs of infrastructure use can be derived from the variable costs. The marginal cost of infrastructure use reflects the variable costs brought about by an additional train using the tracks. According to theory, marginal costs provide a fair and efficient basis for charging for the use of tracks, because they are based on exactly those costs caused by the users of the network.

The Finnish Rail Administration defines the marginal infrastructure costs according to principles adopted from the recommendations made by expert advisors of the European Commission on infrastructure charging (European Commission, 1999).

First, the costs of the infrastructure manager are categorised into fixed and variable costs (Table 3.1). According to the experts, the fixed costs include the costs of land purchases, construction of new rail lines and track lines, enlargement investments and upgrading the service level of existing tracks, as well as administrative costs and other overhead.

Variable infrastructure costs are a part of the costs of maintenance, replacement investments and traffic control. In other words, these cost items are not necessarily fully variable, but the relationships of variable and fixed elements per cost item are not exactly known. Various expert panels have analysed the issue but the outcomes are more or less subjective as well as controversial.

Also the concept of short run is unspecified, and does not relate very well to time concepts in book keeping. Some of the cost items considered at least partially variable are regularly recursive, and the relationship to traffic, up to single trains, is clear. At the same time, some costs are less clearly traffic related. Instead, they may be more dependent on the technical lifecycles of e.g. surface structures, devices and materials. Also maintenance cycles have an impact on the realisation of these costs.

In Finland, variable infrastucture costs are considered to include the costs of all maintenance tasks taking place on the track lines, as well as all costs of replacement investments of surface structures, equipment and devices serving traffic on the track lines. Also winter maintenance and inspections and service of track lines are included in variable costs.

Administrative costs are not considered variable costs, nor are the costs of other authorities (such as the police) and time tabling, which is a cost of the operator. Operation costs of the network (e.g. electricity for heating switches) and traffic control (mainly personnel costs and electricity) are not considered variable costs. Also the costs of telecommunications and costs of disposing of used rail materials and contaminated soils are excluded from the variable costs.

Table 3.1. Classification of cost categories (adopted from European Commission, 1999).

Cost category	**Fixed**	**Variable by infrastructure use and the number of trains/vehicles**
Land purchase	yes	no
Construction of new lines	yes	no
Upgrading/enlargement of existing lines	yes	no
Replacement investments		
Major repairs		
- periodical treatment of structures	partly	partly
- major repairs of bridges, tunnels, switch boxes and platforms performed at larger intervals	partly	partly
Renewal		
- major repairs of bridges, tunnels, switch boxes and platforms, tracks and other facilities which restore full utility value	partly	partly
Construction maintenance		
- minor repairs of bridges, noise protection walls, technical facilities	no	partly
- ballast cleaning, compression	no	partly
Ongoing maintenance and operation		
- winter maintenance	yes	partly
- cleaning, cutting	yes	no
- facility condition checks	yes	partly
- service of bridge beddings, signaling, telecommunications facilities, switch towers	yes	no
- traction current	mainly no	yes
Administration		
- overhead	yes	no
- police	no	yes
- time tabling, train planning	no	yes

3.3 Cost Function and Marginal Costs

The estimation of the variable cost function and derivation of the marginal infrastructure costs is based on the econometric methodology adopted from Johansson & Nilsson (2001) by Idström (2002).

It is assumed that variable rail infrastructure costs are related at least to the utilisation rate per track section, the length of the track section, the total length of tracks on the section, and possibly also to the number of switches and the service level. Utilisation rate is measured as gross tonnes passing through annually. Service level may be measured as e.g. the level of maintenance, speed limits or electrification.

Initially, the relationship of variable infrastructure costs and the explanatory variables is unknown. It can be mathematically depicted by using a Cobb-Douglas type of cost function for each track section (i) for different years (t) as:

$$C_{it} = g(Y_{it}, U_{it}, z_{it}, \varepsilon_{it}) = g(x_{it}, \varepsilon_{it}), \qquad (1)$$

where C_{it} = variable rail infrastructure costs,
Y_{it} = length of the track section (kilometres),
U_{it} = utilisation rate, i.e. total of annual gross tonnes per track section,
z_{it} = service level/quality variable,
x_{it} = function for variable rail infrastructure costs,
ε_{it} = error term and
g = mathematical function.

Because of the expected logarithmic relationship between the variable rail infrastructure costs and the explanatory variables, the cost function is presented in logarithmic form. If the data is estimated separately for each year, the index (t) is not needed. However, a dummy variable (K) is added for representing the level of the variable costs.[1]

In a logarithmic form, the cost function is:

$$\ln C_i = \alpha_0 + \beta^y y_i + \beta^u u_i + \beta_z z_i + \beta_K^y K_i y_i + \beta_K^u K_i u_i + \varepsilon_i \qquad (2)$$

The variable to be explained is the total of variable infrastructure costs *(C)*. The explanatory variables are the track kilometres *(y)*, the utilisation rate *(u)* measured in gross tonnes, a quality indicator *(z)*[2], a dummy for the level of replacement investments *(K)*, and an error term *(ε)*. The β coefficients represent elasticities between each explanatory variable and the infrastructure costs. The parameter values for the explanatory variables are estimated by regression analysis.

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[1] K = 1, if the level of replacement investments per track section exceeds 16 000 euros. Otherwise K = 0.
[2] In the Finnish estimation, the quality of track sections is considered homogenous, and so the variable for service level is omitted from the analysis.

Then, marginal infrastructure costs can be calculated. First, the approapriate unit for the marginal costs, gross tonne-kilometre (G_{tkm}), is created by multiplying the utilisation rate (gross tonnes – U_{it}) of each track section with its length (Y_i).

Next, the cost function is differentiated with respect to changes in traffic, i.e. gross tonne-kilometres ($Gtkm_{it}$):

$$MC_{it} = \hat{\beta}^u \frac{C_{it}}{Gtkm_{it}} \qquad (3)$$

In order to reach a suitable marginal cost estimate, the parameter values of the cost function and fitted costs are added:

$$MC_{it} = \hat{\beta}^u \frac{\hat{C}_{it}}{Gtkm_{it}} \qquad (4)$$

Now, the cost function is of the form $\hat{C}_{it} = \exp(\hat{\alpha}_0 + \hat{\beta}^y y_i + \hat{\beta}^u u_i + z_i \hat{\beta}_z + \hat{\sigma})$, where $\hat{\sigma}^2$ is the estimated *variance* of the error term.

The marginal costs are calculated for each track section and for all years included in the data. Since the marginal costs for different track sections will vary greatly, weighted averages are needed for expressing a representative marginal cost for the entire network, or parts of it. The share of the gross tonne-kilometres for each track section of all the gross tonne-kilometres on the network is used as the weighting factor.

Therefore, the average weighted marginal costs are:

$$\overline{MC}_{it} = \hat{\beta}^u \frac{\sum_i \hat{C}_{it}}{\sum_i Gtkm_{it}} \qquad (5)$$

4 Marginal Costs in Finland in 1997 - 1999

In this section, the results of the previous Finnish marginal cost study by Idström (2002) are presented in brief. The parameter values for the variable cost functions for the years 1997 – 1999 are presented in Table 4.1. The regression analysis reveals that the explanatory variables for the variable infrastructure costs are track length, gross tonnes and the level of replacement investments per track section.[3] The parameter values are converging for all years. Also the fits of the model are reasonable.[4]

Table 4.1. Number of observations, fit and parameter estimates (co-efficients) for the variable cost functions in 1997 – 1999 (Idström, 2002; Ministry of Transport and Communications, 2002).

Year	No. obs.	Fit (R^2)	Constant	Dummy for level of replacement investments	Track length	Gross tonnes
1997	91	0.56	6.30	1.19	0.95	0.29
1998	91	0.48	6.77	1.02	0.77	0.32
1999	91	0.42	6.63	1.13	0.91	0.28

Table 4.2 presents the marginal costs of infrastructure use as weighted averages of all track sections. In 1997 – 1999, the weighted average marginal cost of one tonne-kilometre of train movement on the network was between 0.11 – 0.13 cents.

Table 4.2. Weighted averages of marginal infrastucture costs of track use by section in 1997 – 1999, in nominal prices (Ministry of Transport and Communications, 2002).

Year	cents/gross tkm
1997	0.1263
1998	0.1341
1999	0.1077
Average	**0.1227**

[3] Idström (2002) tested whether maintenance catagory, train speeds or the number of switches explain variable costs. Lesser explanatory power was found.
[4] For results from other countries (e.g. Sweden and Austria), see Thomas (2002).

5 Data for 2000 – 2002

5.1 Network Sections

The data used in estimating the function of variable infrastructure costs, and deriving the marginal costs respectively, was gathered for 93 track sections (Appendix 1). A track section is usually a network link. As far as possible, the network was partitioned by following the split of track sections used in traffic statistics (Figure 5.1). This procedure allows using traffic data that is readily available as it is. Another advantage is that the traffic volumes are homogenous within each track section. Connecting tracks linking the main network with tracks to private industrial or port tracks were excluded.

The following information was collected for each track section:

- length of the track section,
- track kilometres per track section (some sections have multiple tracks),
- technical features: electrification, maintenance standard and number of switches (as presented in the network statement),
- annual gross tonnes – total weight of the locomotives, cars, load and passengers separately for freight and passenger trains that have passed through,
- costs of maintenance that has taken place on the track section, and
- costs of replacement investments that have taken place on the track section.

The track sections vary by length between 3 and 200 kilometres (Appendix 1). The total length of track sections in the data is 5 626 kilometres. As the length of the entire Finnish rail network is 5 850 kilometres (Table 5.1), the data covers 96 % of tracks maintained by the Finnish Rail Administration. The total track length covered in the data is 7 514 kilometres, as there are various sections with multiple tracks on the network.

Table 5.1. Railway network and traffic in 2002 (Finnish Rail Administration, 2003b).

Network length, kilometres	5 850
Total track length, kilometres	8 736
Length of multiple track network, kilometres	507 km (8,7 %)
Length of electrified network, kilometres	2 400 km (41 %)
Train kilometres	
- Passenger trains	30 467
- Freight trains	16 713
Gross tonne-kilometres (1 000 000)	
- Passenger trains	10 826 (33 %)
- Freight trains	21 932 (67 %)
Market share, passenger trains (of passenger kilometres), %	
- of all passenger transport	5
- of all public transport	25
Market share, freight trains (of gross tonne-kilometres), %	25

5.2 Gross Tonnes

The gross tonnes for each track section include the cumulative weight of trains, i.e. of the locomotives, cars, load and passengers, that have passed through the section during a year (Finnish Rail Administration 2000, 2001 and 2002b). Gross tonnes are used as a homogenous variable, which means that the gross tonnes of different types or sizes of trains are categorised in data collection and estimation into just two classes: passenger trains and freight trains. For statistical reasons, passenger-train gross tonnes were collected separately for long distance trains and commuter trains in southern Finland.

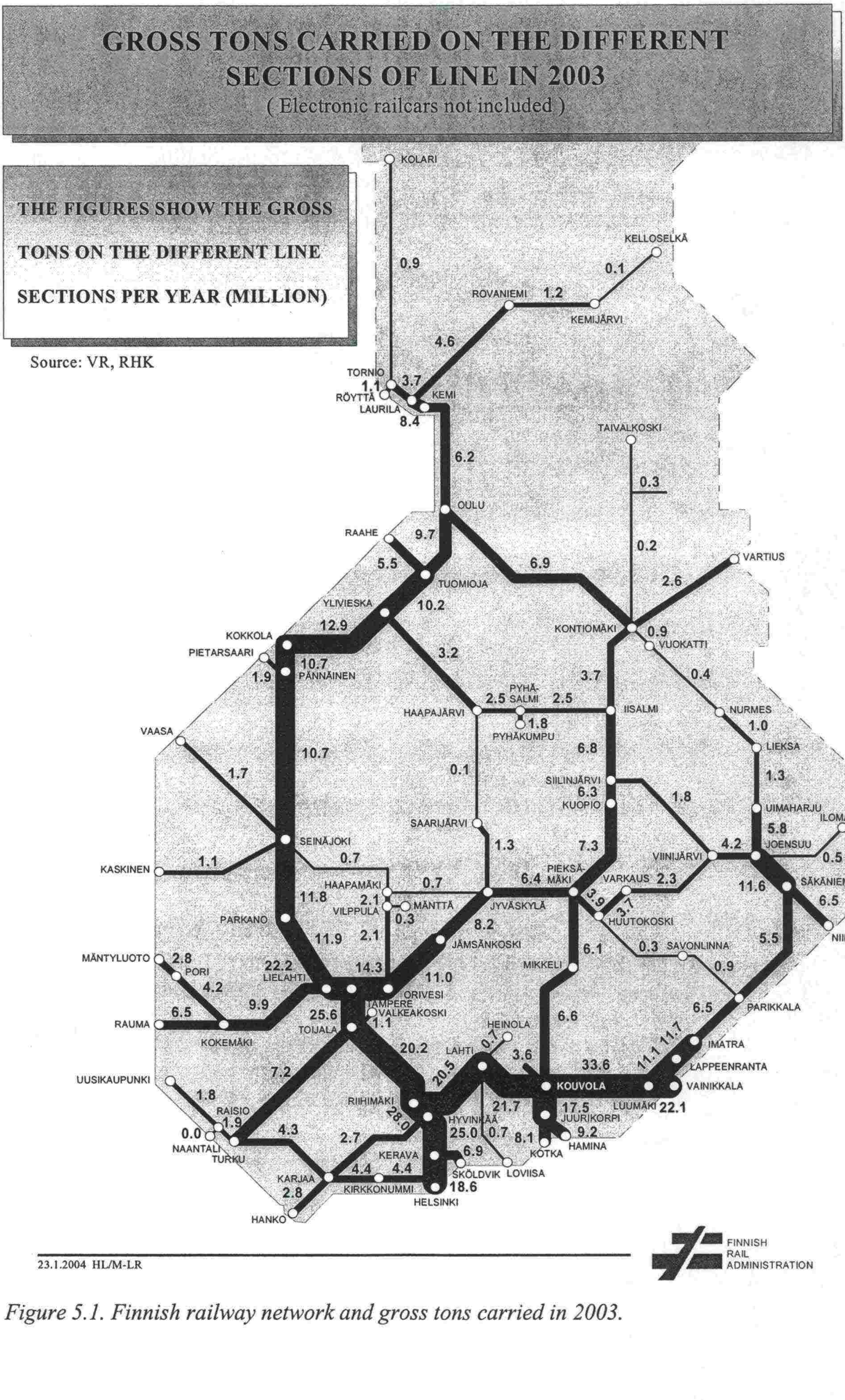

Figure 5.1. Finnish railway network and gross tons carried in 2003.

5.3 Variable Infrastructure Costs

Data on the variable infrastructure costs was obtained by separating the maintenance costs and the replacement investments from the lump of the annual budgets for the Finnish Rail Administration. Therefore, cost categories *Track maintenance operation and use* and *Replacement investments* presented in Table 5.1 were of interest.

Table 5.1. Use of budget funds in 2000 – 2002 (Finnish Rail Administration, 2002a).

Million euros	**2000**	**2001**	**2002**
Track maintenance, operation and use	111.9	120.8	129.6
Replacement investments	152.0	142.5	134.9
Sub Total	***263.9***	***263.3***	***264.5***
(Share of total budget funds)	(66 %)	(69 %)	(63 %)
Development of network	80.9	59.4	52
Particular infrastructure projects (new infrastructure)	-	-	35.1
Traffic control	34.5	37.2	37.8
Administration and other overhead	20.8	23.4	28.4
TOTAL USE BUDGET FUNDS	**400.1**	**383.3**	**417.8**

The cost monitoring systems of the maintenance contractor and the Finnish Rail Administration are used in preparing cost data by track section. There is a separate cost monitoring system for basic maintenance, special maintenance and replacement investments, which all differ in categorisations and principles of registering costs.[5] According to these monitoring systems, the annual use of funds in these cost categories is between 232 – 243 million euros (including overhead, station tracks and marshalling yards; Table 5.2).

Table 5.2. Maintenance costs and replacement investments in 2000 – 2002, including track sections, stations, marshalling yards and overhead (Finnish Rail Administration).

Million euros	**2000**	**2001**	**2002**
Basic maintenance	63	65	65
Special maintenance	25	33	36
Replacement investments	149	134	142
TOTAL	**237**	**232**	**243**

The volume of variable costs allocated to track sections was 145 – 164 million euros/year in 2000 – 2002 (Table 5.3). Comparing with Table 5.2, it can be seen that approximately 66 % of all variable infrastructure costs spent on the entire network (including stations and marshalling yards) were now allocated to track sections.

[5] In Finland, the maintenance of tracks is funded from separate budget catagories. Basic maintenance is a budget item for standard maintenance tasks, whereas special maintenance consist of tasks separately identified and contracted.

Table 5.3. Variable costs allocated to track sections in this study.

Million euros	2000	2001	2002
Basic maintenance	38	38	37
Special maintenance	10	13	15
Replacement investments	116	94	109
TOTAL	**164**	**145**	**161**

The variable costs not allocated to track sections consist of maintenance and replacement investments in station tracks and marshalling yards (the majority of excluded costs), overhead of maintenance costs and other non-relevant/non-variable cost items. There is also an amount of variable costs that can not be allocated to track sections because of incomplete locational information in the cost monitoring systems.

Basic Maintenance

The costs of basic maintenance of track sections are all considered variable infrastructure costs. The basic maintenance of station tracks and marshalling yards was excluded from the data along with maintenance overheads.

All in all, the budget for basic maintenance was 62 – 64 million euros per year in 2000 - 2002 (Table 5.4). The share allocated to track sections was 37 – 38 million euros per year which accounts for approximately 60 % of the overall budget.

The allocation of costs was relatively easy, since the contractor for basic maintenance has a cost monitoring system using 57 track sections. However, some partitioning of the costs had to be made in order to allocate them to the data set with 93 sections.

Table 5.4. Basic maintenance costs allocated to track sections.

Basic maintenance (1000 euros)	2000	2001	2002
Basic maintenance costs allocated to track sections (share of total)	37 900 (61 %)	38 000 (60 %)	36 700 (57 %)
Basic maintenance costs not allocated to track sections	24 100	25 200	27 300
Total	**62 000**	**63 200**	**64 000**

Special Maintenance

Special maintenance consists of maintenance contracted as separate tasks some of which also are replacement investments. In total, the budget for special maintenance was 25 – 36 million euros per year in 2000 – 2002 (Table 5.5). The amount of special maintenance costs allocated to track sections was 10 – 15 million euro per year, which represents approximately 40 % of the total.

Cost allocation was based on the information registered in the cost monitoring system of the Finnish Rail Administration. Excluded cost items consisted mainly of special maintenance of station tracks and marshalling yards, as well as other miscellaneous costs that are not variable infrastructure costs as such. However, a significant sum of special maintenance tasks was excluded because of incomplete information provided by the cost monitoring system.

Table 5.5. Special maintenance costs allocated to track sections.

Special maintenance (1000 euros)	2000	2001	2002
Special maintenance costs allocated to track sections	9 900	13 000	15 400
(Share of total)	(39 %)	(40 %)	(43 %)
Special maintenance costs not allocated to track sections	8 500	12 800	13 700
Track material costs not allocated to track sections	7 000	7 000	7 000
Total	**25 400**	**32 800**	**36 100**

A major part of the cost allocation failures rose from track materials (e.g. attachment materials for rails and sleepers) which were registered as lump sums in the monitoring system. Furthermore, there were some special maintenance tasks that were also registered as lump sums with no detailed information on the location of the contracts in question.[6] These allocation failures significantly reduced the volume of charging relevant variable infrastructure costs included in the data sets.

Replacement Investments

Replacement investments consist of upgrading the tracks and devices that are worn by traffic. These costs were allocated to track sections according to a separate monitoring system.

In total, the budget for replacement investments was between 134 – 149 million euros per year in 2000 – 2002. Of these costs, approximately 94 – 116 million euros per year (75 %) were allocated to track sections (Table 5.6). The majority of the excluded costs were replacement investments of station tracks and marshalling yards. There were also some replacement investments which had taken place on different parts of the network and again could not be allocated to track sections due to lump sum registering in the monitoring system.

Table 5.6. Replacement investments allocated to track sections.

Replacement investments (1000 euro)	2000	2001	2002
Replacement investments allocated to track sections	116 000	93 500	109 000
(share of total)	(78 %)	(70 %)	(77 %)
Replacement investments not allocated to track sections	33 000	40 500	33 000
Total	**149 000**	**134 000**	**142 000**

[6] E.g. rail grinding, ultrasound inspections, maintenance and replacement of rail relays, inverters and switches, as well as inspection and maintenance of bridges.

6 Analysis of the Results

6.1 General

The variable cost functions were first estimated separately for the years 2000, 2001 and 2002, and marginal infrastructure costs were derived respectively. The cost functions were estimated separately for the total of variable costs (basic and special maintenance and replacement investments) and separately for the maintenance cost only.

In order to calculate the marginal costs from a longer time series, a data set of six years (1997 – 2002) was formulated. All variable costs were adjusted to the price level of 2002 by the construction cost index.

The marginal costs of infrastructure use are estimated for each track section, but the primary results are the weighted averages over the whole network. Nevertheless, an example is presented on the variation of marginal costs by track section.

6.2 Cost Functions and Marginal Costs in 2000 – 2002

Cost Functions and Marginal Costs for all Variable Costs

The function for the variable infrastructure costs was first estimated using all variable costs. Observations (track sections) with either no traffic or cost data were omitted from the estimation.

According to the results, the variables explaining variable infrastructure costs weree the traffic volume (gross tonnes), the track length and the level of replacement investments (Table 6.1). Parameter values were converging, and the fits of the models were reasonable at 51 – 56 %. As expected, the elasticities (parameter values) for track length and gross tonnes were below 1. For the years 2000 – 2002, the weighted averages of marginal costs were 0.077 – 0.087 cents/gross tkm (Table 6.2).

Table 6.1. Number of observations, fit and parameter estimates (β-coefficients) for variable cost functions in 2000 – 2002, all variable costs included.

Year	No. obs.	Fit (R^2)	Constant	Dummy for level of replacement investments	Track length	Gross tonnes
2000	90	0.5129	4.4808	1.1383	0.8963	0.2906
2001	86	0.5568	4.5932	1.1185	0.9583	0.2670
2002	88	0.5089	4.5874	0.9525	0.9600	0.2714

Table 6.2. Marginal infrastructure costs in 2000 – 2002, cents/gross tkm, all variable costs included, in nominal prices.

Year	Marginal costs - cents/gross tkm -
2000	0.08729
2001	0.08402
2002	0.07658

The marginal costs of infrastructure use varied hugely by track section (Table 6.3). They were usually lower for track sections that have high traffic volumes in relation to the variable costs. Conversely, track sections with low traffic in relation to the variable costs had a higher marginal cost. However, in weighted averages the extremes effectively even out.

Table 6.3. Smallest and largest marginal costs by track sections in 2002, cents/gross tkm, in nominal prices.

Section	Marginal costs - cents/gross tkm -
Smallest marginal costs	
Uimaharju – Nurmes	0.0186
Ylivieska – Tuomioja	0.02144
Juurikorpi – Hamina	0.02316
Tuomioja – Raahe	0.03272
Säkäniemi – Niirala	0.03313
Largest marginal costs	
Savonlinna – Huutokoski	0.63526
Kemijärvi – Kelloselkä	1.30626
Saarijärvi – Haapajärvi	1.3369
Kankaanpää – Parkano	4.22516
Parkano – Aitoneva	10.27442

Cost Functions and Marginal Costs for Maintenance Costs

The function for the variable infrastructure costs was next estimated with the maintenance cost data only (basic and separate maintenance). This estimation showed not only the marginal costs of maintanance, but the impact of replacement investments on the marginal infrastructure costs. Observations (track sections) with either no traffic or cost data were omitted from the estimation.

According to the results, the explanatory variables were the traffic volume (gross tonnes), the track length and the level of special maintenance, and now also the number of switches in the years 2000 and 2002 (Table 6.6). Parameter values were again converging, and the fits of the models were high at 68 – 73 %. For the years 2000 – 2002, the weighted averages of marginal maintenance costs were 0.018 – 0.025 cents/gross tkm (Table 6.7).

Table 6.6. Number of observations, fit and parameter estimates (β coefficients) for maintenance cost functions in 2000 – 2002.

Years	No. obs.	Fit (R^2)	Constant	Track length	Dummy for level of special maintenance	Number of switches	Gross tonnes
2000	89	0.7168	6.8781	0.6919	0.6116	0.2245	0.1325
2001	85	0.7333	6.1326	0.9837	0.5817	-	0.1551
2002	88	0.6846	6.8341	0.5908	0.4726	0.1959	0.1748

Table 6.7. Marginal maintenance cost of track use in 2000 – 2002, cents/gross tkm, in nominal prices.

Year	Marginal cost - cents/gross tkm -
2000	0.0179
2001	0.02313
2002	0.02458

Cost Functions and Marginal Costs for All Variable Costs as a Six-Year Average

In order to find out the shape of the variable cost function as well as the level of marginal costs with a longer data set, the years 1997 – 2002 were combined into a single data set with 538 observations (some deviating observations/track sections were excluded). All variable costs were adjusted to the price level of 2002 by the construction cost index. Thus, the impact of inflation and changes in construction costs was removed.

According to the results, with all variable costs included in the estimation, the explanatory variables were the traffic volume (gross tonnes), the track length and the level of replacement investments (Table 6.8). Parameter values were again converging, and the fit of the model was 50 %. The shape of the cost function was comparable with the results of the yearly cost functions of 2000 - 2002. The six-year weighted average of marginal infrastructure costs was 0.11 cents/gross tkm (Table 6.9).[7]

Table 6.8. Number of observations, fit and parameter estimates (β-coefficients) for variable cost functions in 1997 – 2002 all variable costs included.

Years	No. obs.	Fit (R^2)	Constant	Dummy for level of replacement investments	Track length	Gross tonnes
1997 - 2002	538	0.5048	4.8913	1.1159	0.89024	0.2809

[7] The six-year weighted average of the marginal maintenance costs was 0.016 cents/gross tkm (with 2002 prices).

Table 6.9. Marginal infrastructure cost of track use, six-year weighted average, all variable costs included, cents/gross tkm, at the price level of 2002.

Years	Marginal cost - cents/gross tkm -
1997 - 2002	0.10814

6.3 Comparison of Calculations for 1997 – 1999 and 2000 – 2002

Marginal Costs and Variable Cost Data

Next, the marginal costs, cost functions and data sets for the estimations of 1997 – 1999 and 2000 – 2002 are compared. The comparisons are made on the results of estimations with all variable costs included.

The marginal costs of infrastructure use as weighted averages of all track section were, in nominal prices (Table 6.10):

- 0.11 – 0.13 cents/gross tkm in 1997 – 1999 and
- 0.077 – 0.087 cents/gross tkm in 2000 – 2002.

There was a significant change in the level of the marginal infrastructure costs between the two studies. They were approximately one quarter lower in 2000 – 2002. The difference would be even bigger if the marginal cost were presented in fixed prices.

Table 6.10. Weighted average of marginal infrastructure costs of track by section in 1997 – 2002, cents/gross tkm, in nominal prices.

Year	1997	1998	1999	2000	2001	2002
Marginal cost	0.12443	0.13407	0.11592	0.08729	0.08402	0.07658

Table 6.11 presents the parameter estimates for the cost functions for the years 1997 – 2002. The parameter values converge relatively well, but do reflect the lower volume of variable infrastructure costs in the data sets of 2000 – 2002.

Table 6.11. Number of observations and parameter estimates (β coefficients) for variable cost functions in 1997 – 2002.

Year	No. obs.	Constant	Dummy for level of replacement investments	Track length	Gross tonnes
1997	91	4.7765	1.1545	0.9498	0.2780
1998	91	4.9918	1.0214	0.7720	0.3167
1999	91	4.7986	1.0177	0.9019	0.2896
2000	90	4.4808	1.1383	0.8963	0.2906
2001	86	4.5932	1.1185	0.9583	0.2670
2002	88	4.5874	0.9525	0.9600	0.2714

Explanations to the reduction of the marginal costs mostly deal with the volume of variable costs allocated to track sections (Table 6.12). In turn, the amounts of variable costs change due to fluctuations in annual budgets, and due to changes in the manner in which variable costs are registered in the cost monitoring systems.

The single most important reason for the drop in the variable infrastructure costs is the significant reduction in the replacement investment budgets in 2000 – 2002 compared with 1997 - 1999 (Table 6.13). The replacement investment budgets do not follow actual needs but reflect the scarcity of government funding.

In the cost monitoring systems, the share of overhead costs had increased. Also lump sum registering of certain types of maintenance works and replacement investments had occured. Lump sums could not be allocated to track sections because it was not known at which locations these maintenance or replacement investment contracts had taken place.

Therefore, in order to prevent such losses of variable cost data, each euro of labor and/or material costs of works performed on the network should be provided with an address by track section. The level of precision and locational detail of registering costs in monitoring systems is a crucial issue.

Several siding track sections leading to industrial compounds that were separately monitored prior to the previous study (1997 – 1999), had since then been integrated into larger units in cost monitoring (i.e. the number of track sections separately monitored has reduced). Some of the track sections that were no longer separately monitored had an impact on the level of the marginal costs in the previous study.

A small but a natural reason for a decreasing trend in the maintenance costs was the cost efficiency target, which aims at reducing maintenance costs of by a couple per cent per year.

The timing of special maintenance and replacement investments also had an impact on the variable costs allocated to track sections. Due to the periodical rotation of works, there may have been relatively more variable costs allocated to track sections with high traffic volumes in some years, which tends to lower the weighted average of marginal costs. Another issue of timing of the works concerns the balance of replacements investments taking place on track lines and stations/marshalling yards each year.

Table 6.12. Variable infrastructure costs allocated to track sections in 1997 – 2002.

Million euros	**Data 1997 - 1999**			**Data 2000 - 2002**		
	1997	**1998**	**1999**	**2000**	**2001**	**2002**
Basic maintenance	53	49	48	38	38	37
Special maintenance	19	17	18	10	13	15
Replacement investments	156	174	141	116	94	109
TOTAL	**228**	**240**	**207**	**164**	**145**	**161**

Table 6.13. Use of budget funds on track sections, station tracks and marshalling yards in 1997 – 2002 (nominal prices; excluding development investments; Finnish Rail Administration).

Million euros	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**
Maintenance						
- basic maintenance	75	67	67	63	65	65
- special maintenance	28	25	28	25	33	36
Replacement investments	188	191	177	152	143	135
TOTAL	**291**	**283**	**272**	**240**	**241**	**236**

7 Assessment of Marginal Cost Estimation

7.1. Strengths and Weaknesses

Strengths

The methodology applied in Finland for setting charges on rail infrastructure use is theoretically sound and based on a detailed analysis of the costs relevant for charging. The methodology is transparent since the relevant cost items, as well as the estimation methodology, are clearly reported.

The Finnish railway statistics and the systems for monitoring the infrastructure costs allow estimation of marginal costs of a very fine partitioning of the network. Therefore, the procedure is precise and would also allow differentiating the charges in different parts of the network.

From the users' perspective, the charges are fair since they are based on only those costs which depend on the use of tracks. In comparison with average cost pricing (see section 7.2), fairness is evident. Finally, the methodology is in line with the requirements of the Directive on Railway Charges.

Weaknesses

The methodology is demanding with respect to data. Precision is needed in the cost categories used, and precision is also expected from railway statistics and the cost monitoring systems. The variable infrastructure costs relevant for charging should be fully allocated to track sections. These requirements add to the expectations for the capability of cost monotorin, as well as for setting up the data for estimation. In other words, resources are required for developing and maintaining the cost monitoring systems.

The methodology is evidently very sensitive to changes in cost monitoring as well as inaccuracies of the systems. This is unfavourable for the pricing objectives of the rail administrator. The system can also be considered rather challenging mathematically.

7.2 Comparison with Average Cost Pricing

Average cost pricing is mathematically very easy and therefore attractive. A certain sum of chargeable costs is simply divided by e.g. annual gross tonnes. However, according to economic theory, this results in unoptimal pricing. Average costs are usually higher than marginal costs, which may lead to overcharging that hampers necessary traffic. Charges would be at an unjustified level since they are not based on the actual wear and tear of the tracks caused by the movement of a single train. Fair pricing means that charges are based exactly on the costs imposed by the user.

Table 7.1 presents three alternative bases for setting average infrastructure charges as an alternative for marginal cost pricing. Average costing can be based either on:

- those variable costs that were allocated to track sections in this study (1),
- all maintenance costs and replacement investments on tracks sections, station tracks and marshalling yards (2), or
- budgets for basic infrastructure management (3), excluding development investments.

The results clearly indicate the difference in average and marginal cost pricing. According to this study, the marginal costs for infrastructure use were 0.077 – 0.087 cents/gross tkm in 2000 - 2002, whereas the average costs were between 0.44 – 1.00 cents/gross tkm depending on the basis of costing. The marginal-cost based charges are only a fraction of the average-cost based ones.

Table 7.1. Average variable costs of infrastructure use, cents/gross tkm, in 2000 - 2002.

Costing basis	**2000**	**2001**	**2002**
Gross tonne-kilometres	33 148 000 000	32 608 000 000	32 759 000 000
1) Variable costs on track section as in this study			
Costs in total (euros)	164 000 000	145 000 000	161 000 000
Average costs (cents/gross tkm)	0.49	0.44	0.49
2) Maintenance and replacement costs on track sections, stations and marshalling yards			
Costs in total (euros)	240 000 000	241 000 000	236 000 000
Average costs (cents/gross tkm)	0.72	0.74	0.72
3) Budget for basic infrastructure management (excluding development investments)			
Costs in total (euros)	318 400 000	322 100 000	327 800 000
Average costs (cents/gross tkm)	0.96	0.99	1.00

8 Conclusions

The methodology for estimating marginal infrastructure costs used by the Finnish Rail Administration is applicable and can be used for deriving infrastructure charges also in the future. No fundamental issues undermining the capability of the methodology have been noted. The methodology fulfills the requirements set in the Directive, and it is fair for the users. However, the process of setting up variable cost data does require development of systematicity and coverage.

The main results for the years 2000 – 2002 were (in nominal prices):

- Calculated from all variable costs, the weighted average of the marginal costs were 0.077 – 0.087 cents/gross tonne-kilometre.
- Calculated from maintenance costs, the weighted average of the marginal costs were 0.018 – 0.025 cents/gross tonne-kilometre.

The main results for the years 1997 – 2002 were (in price level of 2002):

- Calculated from all variable costs, the weighted six-year average of the marginal costs were 0.11 cents/gross tonne-kilometre.
- Calculated from maintenance costs, the weighted six-year average of marginal costs were 0.016 cents/ gross tonne-kilometre.

Compared with the results of the previous study (1997 – 1999), the level of the marginal costs calculated from all variable costs decreased significantly. The main reason was that the budgets for replacement investments were significantly lower in 2000 – 2002.

Marginal costs were calculated according to the realized variable infrastructure costs of past years, which is not necessarily equivalent to the optimal level of infrastructure financing. Thus, constantly varying budgets can complicate infrastructure charging because budget variations lead to changes in the annual realization of variable costs, which in turn leads to short-run variations in marginal costs.

The loss of variable cost data rose from the way in which variable costs are registered in the cost monitoring systems. Not all variable cost items could be allocated to track sections due to imperfect information on the location of maintenance and replacement investments. Also the share of costs registered as overhead had slightly risen. Therefore, there is full justification to say that the above results are an underestimate of the marginal infrastructure costs.

The way the results from the six-year data set present marginal costs evens out the impacts of annually fluctuating budgets and inflation. Such a result is perhaps the most justifiable basis for setting infrastructure charges.

As noted above, the most important development issue of Finnish marginal cost charging concerns cost monitoring over the network. Cost monitoring has not been developed from the perspective of setting marginal infrastructure charges. However, the requirements set by charging objectives will have to be taken into account in the future.

All variable costs that occur on track sections because of maintenance or replacement investments need to be systematically and completely registered by precise location. Otherwise marginal costs will be underestimated also in the future. In 2004, the Finnish Rail Administration has begun to run a system of regional network bookkeeping, which may create a cost database ideal for infrastructure charging.

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APPENDIX 1 TRACK SECTIONS

No.	Section	Length, km	No.	Section	Length, km
1	Helsinki - Pasila	3	48	Säkäniemi - Border	33
2	Pasila - Hiekkaharju	14	49	Joensuu - Ilomantsi	71
3	Hiekkaharju - Kerava	12	50	Turku - Toijala	128
4	Pasila - Kirkkonummi	35	51	Toijala - Valkeakoski	17
5	Huopalahti - Vantaankoski	9	52	Pieksämäki - Jyväskylä	80
6	Kerava - Hyvinkää	30	53	Toijala - Tampere	40
7	Hyvinkää - Riihimäki	12	54	Vilppula - Mänttä	9
8	Kerava - Sköldvik	33	55	Lielahti - Kokemäki	91
9	Kirkkonummi - Karjaa	49	56	Kokemäki - Pori	38
10	Hyvinkää - Karjaa	99	57	Tampere - Lielahti	6
11	Karjaa - Hanko	53	58	Lielahti - Parkano	69
12	Riihimäki - Toijala	76	59	Parkano - Seinäjoki	84
13	Riihimäki - Lahti	59	60	Kankaanpää - Parkano	48
14	Turku - Raisio	8	61	Parkano - Aitoneva	22
15	Raisio - Uusikaupunki	58	62	Tampere - Orivesi	42
16	Karjaa - Turku	113	63	Orivesi - Jämsänkoski	60
17	Lahti - Kouvola	62	64	Jämsänkoski - Jyväskylä	53
18	Kouvola - Juurikorpi	36	65	Orivesi - Haapamäki	72
19	Juurikorpi - Kotka	18	66	Haapamäki - Seinäjoki	118
20	Kouvola - Luumäki	58	67	Kokemäki - Rauma	47
21	Kouvola - Mikkeli	113	68	Pori - Mäntyluoto/Tahkoluoto	21
22	Mikkeli - Pieksämäki	71	69	Jyväskylä - Äänekoski	47
23	Kouvola - Kuusankoski	8	70	Äänekoski - Saarijärvi	28
24	Juurikorpi - Hamina	19	71	Saarijärvi - Haapajärvi	135
25	Lahti - Heinola	38	72	Jyväskylä - Haapamäki	78
26	Lahti - Loviisa	78	73	Seinäjoki - Vaasa/Vaskiluoto	74
27	Luumäki - Vainikkala	33	74	Seinäjoki - Kaskinen	112
28	Luumäki - Lappeenranta	28	75	Seinäjoki - Kokkola	133
29	Lappeenranta - Imatra	39	76	Kokkola - Ylivieska	79
30	Imatra - Parikkala	61	77	Ylivieska - Tuomioja	68
31	Parikkala - Säkäniemi	93	78	Tuomioja - Oulu	54
32	Säkäniemi - Joensuu	37	79	Pännäinen - Pietarsaari	11
33	Parikkala - Savonlinna	59	80	Tuomioja - Raahe/Rautaruukki	34
34	Savonlinna - Huutokoski	75	81	Ylivieska - Haapajärvi	55
35	Pieksämäki - Kuopio	89	82	Oulu - Kontiomäki	166
36	Kuopio - Siilinjärvi	25	83	Oulu - Kemi	106
37	Siilinjärvi - Iisalmi	60	84	Kemi - Laurila	8
38	Pieksämäki - Huutokoski	31	85	Laurila - Rovaniemi	106
39	Huutokoski - Varkaus	18	86	Laurila - Tornio	18
40	Varkaus - Viinijärvi	101	87	Tornio - Kolari	183
41	Viinijärvi - Joensuu	33	88	Tornio - Röyttä	11
42	Viinijärvi - Siilinjärvi	112	89	Rovaniemi - Kemijärvi	83
43	Iisalmi - Kontiomäki	109	90	Kemijärvi - Kelloselkä	78
44	Iisalmi - Haapajärvi	99	91	Murtomäki - Otanmäki	25
45	Joensuu - Uimaharju	50	92	Taivalkoski - Kontiomäki	156
46	Uimaharju - Nurmes	109	93	Kontiomäki - Vartius	95
47	Nurmes - Kontiomäki	109		**Total length**	**5 626**

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